TNO report
FEL-97-A219

RTPI Prototype
Final Report

19971203 202

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Date
September 1997

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Classification		
Classified by	:	LTZ A. Bezemer
Classification date	:	25 August 1997
Title	:	Ongerubriceerd
Managementuittreksel	:	Ongerubriceerd
Abstract	:	Ongerubriceerd
Report text	:	Ongerubriceerd
Appendix A	:	Ongerubriceerd
Copy no	:	9
No of copies	:	30
No of pages	:	26 (incl appendix, excl RDP & distribution list)
No of appendices	:	1

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Managementuittreksel

Titel	:	RTPI Prototype Final Report
Auteur(s)	:	Ir. A.M. van der Weiden
Datum	:	september 1997
Opdrachtnr.	:	A93KM754
IWP-nr.	:	771
Rapportnr.	:	FEL-97-A219

Het project 'RTPI prototype' (Real-Time Performance Indicator) betreft een ontwikkelopdracht voor de Koninklijke Marine ten behoeve van de mijnenjacht. Het systeem heeft tot doel om door middel van simulatie een indicatie te geven van de karakteristieke detectiebreedte (A waarde) en de karakteristieke detectiekans (B waarde). De simulatie maakt gebruik van invoer gegevens die zowel met de hand ingegeven kunnen worden als ter plekke gemeten kunnen worden met hiertoe door het MEOB ontworpen en gebouwde apparatuur. Voor de simulatie wordt gebruik gemaakt van een aangepaste versie van HUNTOP. Hardwarematig is het FEL-deel van RTPI gebaseerd op OPPAS waaruit het ook een deel van de meetgegevens betrekt.
Dit rapport beschrijft de ontwikkeling van het prototype en de daarmee samenhangende ontwerp beslissingen. De specificaties, het ontwerp, de implementatie en de tests zijn gedocumenteerd in (deliverable) werkdocumenten.
In paragraaf 6.2 wordt ingegaan op de integratie van een performance indicator aan boord. De nieuwe scheepsconfiguratie wijkt echter dermate sterk af van de huidige dat de RTPI niet zonder meer geschikt is voor de nieuwe scheepsconfiguratie. Dit rapport bevat dan ook niet de specificatie voor de serieproduktie.
Het RTPI project is gestart in augustus 1994, in oktober van dat jaar zijn de specificaties opgeleverd aan de KM ter goedkeuring, waarna het ontwerp en de implementatie gestart zijn. In maart 1996 heeft de Factory Acceptance Test plaatsgevonden en in mei 1996 is het systeem aan de KM opgeleverd. Eveneens in mei is het project OPEVAL (OPErationele EVALuatie) gestart om de bruikbaarheid van het concept in de praktijk te beproeven en enkele specifieke aspecten van de data acquisitie nader te beschouwen.
Naar aanleiding van de ervaringen van de eerste maanden zijn in juli 1996 enkele verbeteringen in het systeem aangebracht. Deze verbeteringen betreffen wensen van de KM ten aanzien van het bedieningsgemak en enkele diagnostische routines.

Management summary

The project 'RTPI prototype' (Real-Time Performance Indicator) is an assignment by the Royal Netherlands Navy to develop such a system for mine hunting operations. The purpose of the system is to give indications of characteristic detection width (A value) and characteristic detection probability (B value) by means of simulation. The simulation uses input values which can be entered manually or can be measured on location with equipment developed by MEOB. The simulation kernel is a specially adapted version of HUNTOP (HUNTing OPerations). The RTPI hardware is based on OPPAS (OPerational PAP Simulator) from which RTPI also obtains some of its measurements.
This document describes the development of the prototype and the design decisions involved in this process. The specifications, design, implementation and tests are documented in separately delivered documents. Paragraph 6.2 addresses the integration of a performance indicator aboard a mine hunter. The new mine hunter configuration however differs considerably from the current configuration. As such the current RTPI does not suit the new configuration and therefore this report does not contain a specification for the production of RTPIs.
The RTPI project was started in August 1995, in October of that year the specifications were delivered to the Navy for approval. After approval, RTPI was designed and implemented resulting in a Factory Acceptance Test in March 1996. The system was finally delivered to the Navy in May 1996. In the same month the OPEVAL (OPerational EVALuation) was started to assess the usefulness of the concept in an operational context and to evaluate some specific aspects of the data acquisition.
The trials conducted during the first months of operation resulted in several enhancements to the system. The enhancements pertain to demands by the Navy for improved ease of use and some diagnostic routines. These improvements were implemented in July 1996.

Contents

1. Abstract

The 'RTPI prototype' system is a precursor to the RTPI series production. Its intent is to gain experience with such a system during an 'operational evaluation' of the prototype system. RTPI (Real-Time Performance Indicator), in the CUP (Capability UPgrade) called SPI (Sonar Performance Indicator), is a system which assesses the quality of mine detection using a sonar. The system is designed for the 'Alkmaar' class mine hunters equipped with dedicated instrumentation for measurement of the sound velocity profile, the absorption and reverberation in the vicinity of the hunter at the time of the operation (hence real-time). The quality of mine detection is expressed as a detection probability curve which indicated the detection probability as a function of the athwart distance and as A and B values which indicate the characteristic detection width and the characteristic detection probability.

The system is enclosed in the OPPAS rack and uses many of the OPPAS system interfaces. RTPI incorporates the HUNTOP simulator which simulates a mine-hunting operation (detection phase) using real-world environment data and computes the desired probabilities.

This report describes the development of the TNO-FEL part of the system. It presents an overview of the system and elaborates on design decisions which had to be made in the course of development. This report does not contain documentation about the system, the system is documented in the documents listed in appendix A.

Recommendations on future research, tools and enhancements are made in chapter 6.

2. Introduction

2.1 RTPI system

The "Real-Time Performance Indicator" (RTPI) is a system which estimates and predicts the quality of a mine hunting operation by means of simulation using (real-time) measured environmental data. These measurements include water parameters at various depths and reverberation conditions. The quality of the hunting operation (detection phase) is expressed in both a P(y) curve (athwart detection probability) and A/B values (characteristic detection width and characteristic detection probability).

2.2 RTPI report

This document is the last in a series of RTPI documents which together make up the total system documentation of the project "RTPI prototype". Chapter 5 and Apendix A give an overview of all (TNO-FEL) documents produced in the course of the project. The documentation is not concise in the sense that some sub-systems, though essential to RTPI, are not documented by TNO-FEL because they are not TNO-FEL systems. Also source code is not provided because the intellectual property remains at TNO.

2.3 RTPI project

At the date of publishing of this report, the RTPI system is in the state of "operational evaluation" which is not part of this project. The RTPI project is in the state of 'after sales' and only corections to bugs will be applied to the system. No more enhancements to the current version (1.4) are currently envisioned. Consequently this report describes the current (stable) version of the RTPI system.

3. System Architecture

The system architecture is defined by the RTPI specification called "Real-Time Performance Indicator" voor de Mijnenjacht, een Systeemspecificatie' by Diepstraten and Vernooy [FEL-92-A418]. After the contract was awarded the system was further specified in the DMKM approved documents 23273.400/BB01 V1.0, 23273.400/BB02 V1.0 and 23273.400/BB03 V1.0. The interfaces between RTPI sub-systems were defined in the DMKM approved documents 23273.401/BC01 V1.0, 23273.402/BC01 V1.0 and 23273.403/BC01 V1.0. In the implementation phase of the project minor changes to the specification and interface definition became necessary. Therefore the following documents were updated:

- 23273.400/BB02 V1.1 User Interface Document;
- 23273.402/BC01 V2.1 RTPI-MEOB IDD;
- 23273.403/BC01 V2.1 RTPI-HYDRAUT IDD.

The user interface document specifies the menu structure and the screen lay-outs. The menu structure is adhered to but the actual screen lay-outs sometimes differ for reasons of space efficiency and greater ease-of-use.

3.1 Hardware architecture

3.1.1 System overview

The hardware architecture is shown in Figure 1. It should be noted that the RTPI processing unit with the disk drives is enclosed in the OPPAS rack and that OPPAS and the MEOB interface are mounted in the HYDRAUT cabinet. The probe and winch are mounted on deck and the reverberation unit is mounted in the sonar array.

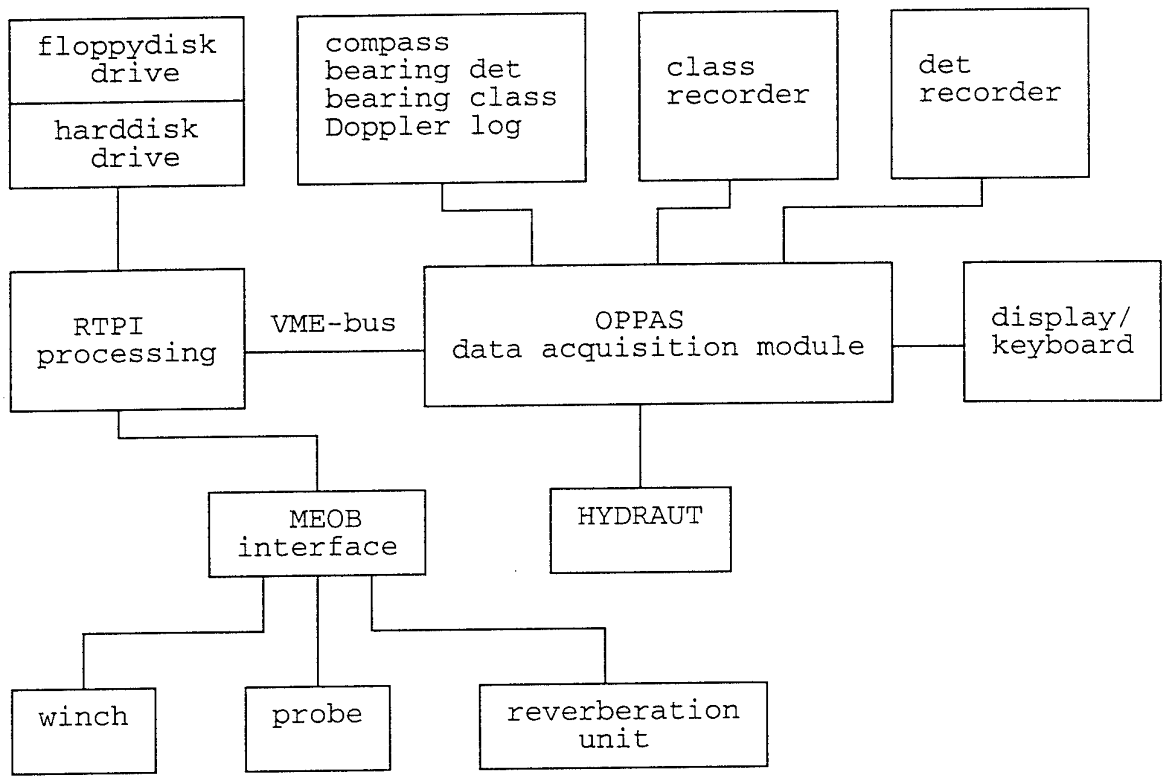

Figure 1: *Hardware configuration.*

The interfaces to the display unit, sonar and Doppler-log were already present in OPPAS. The interfaces to Hydraut and the MEOB interface (measurement unit) as well as the communication over the VME-bus were designed specifically for this project and are documented in the specification documents mentioned and in the design documents 23273.610/CB01 and 23273.620/BN01. The interfaces between the measurement unit and the probe, winch and reverberation unit are beyond the scope of the TNO-FEL documentation.
In order for the system to function properly, all systems shown in Figure 1 must be powered-on. When the measurement unit is off, no communication with the sensors is possible and RTPI will sound the beeper repeatedly until the connection is established. When the Hydraut is off or when the connection is broken, RTPI measurements cannot be stamped with the correct time and location information. Also real-time simulations are not possible because of the lack of speed and direction information. When the log is off, log information will not be logged. When the sonar display units are off, the recorder circuit boards will not be powered and RTPI will be slowed down due to communication failures with these boards.

3.1.2 Changes to existing hardware

The RTPI processing board and interconnect board fit in two free slots of the OPPAS VME backplane. The disk drives are mounted in the original position of

the battery compartment. The battery compartment has been moved to a position just below its original location. During normal OPPAS operation, the connection between the PAP console and the PAP is broken. When RTPI is operational this connection is re-established by software. However, when powering up or when executing OPPAS, the PAP is still disconnected. Without the connection the PAP releases its guide-rope and MDW (Mine Disposal Weapon). This situation cannot be avoided by the system but must be avoided by procedures.

3.2 Emulators

In order to facilitate concurrent engineering at MEOB, Van Rietschoten&Houwens and TNO-FEL, emulators were designed and built. These emulators were used as executable specifications during development and as data entry devices during testing. The emulators were developed early in the project and tested extensively. Parts of the code were later used in the actual RTPI code.

3.3 Software architecture

RTPI consists of several computers, each running their own software. RTPI involves at least the following computers:
- OPPAS PME board, procured and programmed by TNO, runs start-up code and data acquisition code (Hydraut, sonar etc.).
- XVME board, procured and programmed by TNO, runs the core of the RTPI software.
  Measuring unit, developed by MEOB, runs data acquisition and winch control.
- Probe computer, developed by MEOB, runs data acquisition software.
- Emulators, programmed by MEOB and FEL, used during development.

Software specifically designed or modified for RTPI is also present in the winch, sensors and Hydraut.

3.3.1 Overview

In this chapter, we will concentrate on the software running on the RTPI processing board (XVME-674). This software was designed according to the object-oriented methodology and is entirely written in C++. There is a source module for each object class. We distinguish two types of objects; those which are created and destroyed in the course of processing (bottom objects, co-ordinates, etc.) and those that are created at start-up and destroyed at exit (user_interface, simulator, database etc.). The latter type is often associated with a configuration file which it reads at creation. The objects can also be categorised as belonging to three different processes: System control, Sensor control and Performance calculation. System control encompasses the user_interface, input/output (I/O) objects and the database. Sensor control is taken care of by the measuring_unit

object and Performance calculation is done by the simulator object with its associated model objects.

3.3.2 The main process

The main process first creates all permanent objects needed for RTPI operation and establishes connections between those objects. Once this is completed, the user interface is started and RTPI is operational. When the user selects 'end RTPI', all objects are destroyed and the program terminates. A batch file is responsible for the restart of RTPI and for possibly other house-keeping tasks (maintaining system integrity, deletion of temporary files, user hooks etc.).

3.3.3 System control

The RTPI System control portion is documented in reports 23273.641/BH01 and 23273.642/BH01. The first document describes the user interface whereas the latter describes the database. The I/O objects (keyboard, screen, OPPAS and printer) are not covered in these documents. The functionality of the keyboard, screen and OPPAS objects is described in the OPPAS software document 23273.620/BN01 because communication with these devices takes place through OPPAS. The printer object provides methods to initialise the printer and print a character on the printer.
The last object that must be mentioned in this chapter is the 'RTPI_values' object which is responsible for the administration of data from the various sources (e.g. measured data or user defined data). In fact it is a repository for all kinds of data with 'get' and 'set' operators for each data item.

3.3.4 Sensor control

Sensor control is implemented through the Measuring_unit object and is documented in report 23273.631/BH01.

3.3.5 Performance calculation

The performance is computed by the 'Simulator' object. The simulator object is connected to many model objects which model parts of the real world like 'ship', 'water', 'mine' etc. These objects are modelled in document 23273.650/BB01. These objects together are in effect the HUNTOP (HUNTing OPeration) simulator. Several enhancements were made to HUNTOP in order to make it faster and in order to allow the use of real-time measured data.

4. Implementation

4.1 User interface

As long as RTPI is active, the user interface is polling for events to happen and subsequently dispatch to a function handling the event. There are basically three types of events. Keyboard events, timer events and exception events. Keyboard events correspond to a key-press and indicate that the user wants RTPI to perform some action. Timer events indicate that it is time to perform some action, usually to gather data or write a log-record. Exceptions are messages from other sub-systems which indicate that something has happened. This may vary from perfectly normal events like 'bottom hit' to fatal events like 'no communication' with the measurement unit. Exceptions are always reported on the screen. The possible exceptions, menu structure and screen lay-outs are described in documents 23273.400/BB02 (User Interface Document) and 23273.700/DA01 (User's manual).

4.2 System interfaces

The RTPI processing unit has interfaces (directly or indirectly) to the following systems:
- Detection sonar controls
- Doppler log
- Winch
- Probe
- Detection sonar reverberation signal
- Hydraut
- Display/keyboard unit.

4.2.1 Detection sonar
The data from the sonar is used to compute the sonar footprint. The settings of power and pulse width are used to compute the contrast. The values used to be updated every 5 seconds but due to instability of the signal for the depression angle, the frequency was increased to once per second. The depression data is then filtered by an alpha filter with α=0.25. This means that fluctuations are damped with a factor of 0.25 but that it takes longer to achieve a certain accuracy. With the current setting, the accuracy is 18% after 5 samples (seconds). I.e. when a step of 4 degrees is applied to the filter (ignoring fluctuations), the output of the filter will change to 1 deg. immediately and pass through 1.75, 2.31, 2.73, 3.05 and reach 3.29 after 5 seconds. This value is 0.71 degrees (or 18%) from the desired value of 4 degrees. The following table shows the relationship between accuracy, alpha and number of samples.

Table 1: Relation between damping, accuracy and delay.

alpha	accuracy (%)	samples
0.25	18%	6
0.25	10%	8
0.25	1%	24
0.20	10%	10
0.37	10%	5
0.37	1%	10
0.60	1%	5

The table shows that there is a trade-off between damping, accuracy and delay. A sonar log record is written to disk whenever a button setting changed or the (filtered) depression angle changed by more than a pre-defined tolerance (0.5 degrees).

4.2.2 Doppler log

The data from the ship's log is only used for logging (for later analysis). In order to conserve disk space, the logging interval is set rather long (10 minutes). All four values from the log are recorded even when only the speed relative to the water is available. A new record is written only when any of the speeds has changed by more than a pre-defined tolerance (1 m/s).

4.2.3 Winch

The only signals retrieved from the winch are its status bits. The 'bottom hit' and 'to block' signals are in fact probe signals but are processed as though they were winch signals. The winch state is updated on the screen every second. Winch activity is not logged. When the probe hits the bottom, the winch will raise the probe 2 meters unless the probe is stuck or the depth sensor is defective (RTPI will fail the attempt after 6 seconds). From release 1.1 on, RTPI will not attempt to raise the probe 2 meters after a bottom hit when the probe is not submerged. This feature was added in order to make it possible to put the probe on deck in an upright position. In release 1.0 the probe was raised 2 meters immediately after hitting the deck.

4.2.4 Probe

The probe update time is pre-set to once every 2 seconds. At a winch speed of 0.5 m/s, this corresponds to a resolution of 1 meter. Every interval, the following data is retrieved: depth, sound velocity, pH, salinity, temperature and a sound velocity computed from the other parameters.
The measured values are checked against their allowable limits and when they differ from the previous measurement (by at least their resolution), they are noted as a new value in the curve. The pH value is treated slightly different however because this is not measured as a curve but as an averaged value. Because the pH sensor is quite slow (15 s settling time), averaging starts after 15 seconds (7.5m depth). When the depth is less than 7.5m, a default pH value of 8.3 is reported.

The range checking on the measured values is actually ineffective because range checking is done by the measurement unit (MEOB part) and is signalled to the processing unit in a separate status bit.

Table 2: Range and resolution of measured values.

	minimum	maximum	resolution	unit
depth	0	200	0.1	m
temperature	-5	105	0.1	°C
salinity	0	1000	0.1	p.p.t.
sound velocity	1400	1600	0.1	m/s
pH	0	14	0.1	

4.2.5 Reverberation

Reverberation is measured with one of the hydrophones in the sonar array, i.e. the signal is NOT taken from a bundle. This means that the sensitivity is nearly omni-directional. This kind of measurement is all-right for noise measurements because noise is not correlated to the emitted signal. On the other hand, it is less correct for reverberation measurement because it does not take into account the directivity index of the array. Measuring a bundle instead of a hydrophone is much more complicated because the signal is compressed by the AGC (Automatic Gain Control). Measuring the value of the AGC as well is difficult because the AGC-signal is highly non-linear and temperature dependent. REACT simulations however show that adding an offset to the reverberation+noise signal in dB (applying a constant gain) gives a good approximation of the signal in a bundle. An estimate of this gain is 17dB but must be determined by experiments during the operational evaluation.
The measurement of the reverberation is linear in dB (i.e. logarithmic) with a dynamic range of almost 80dB which is more than adequate as experiments show a dynamic range (in the useful region) of 50 to 60dB. The reverberation signal is sampled every 10ms. Depending on sonar range this yields between 55 and 120 samples per sonar ping. Multiple data-sets from pings are averaged (from ping to ping) using an alpha filter. The current implementation uses $\alpha = 0.167$.

Table 3: Relation between accuracy and settling time.

step size [dB]	accuracy [dB]	samples	time [m:s]
10	0.1	25	2:05
10	1.0	13	1:05
20	0.1	29	2:25
20	1.0	16	1:20
40	0.1	33	2:45
40	1.0	20	1:40
80	0.1	37	3:05
80	1.0	24	2:00

Table 3 shows the relation between absolute step-size, absolute accuracy and the settling time of the filter for the given alpha. Not every ping is used in the computation. In order to reduce computational overhead, only one ping is sampled every 5 seconds. The filtered value is logged to disk once every 4 minutes which is well beyond the settling time. The filter will reduce a sine-shaped modulation with a 2 minutes cycle approximately a factor of 2 in amplitude.
The noise value is estimated from the measured (and filtered) curve by averaging all samples beyond 0.5 seconds. This, under the assumption that reverberations have faded away after 0.5s, REACT simulations support this assumption. Operational data must show whether this time needs to be adjusted and whether different gains need to be applied to reverberation and noise.
In RTPI release 1.2 and above, the distinction between reverberation and noise for measured reverberations has been dropped. The contrast is determined as the difference between (computed) echo level and measured background level.

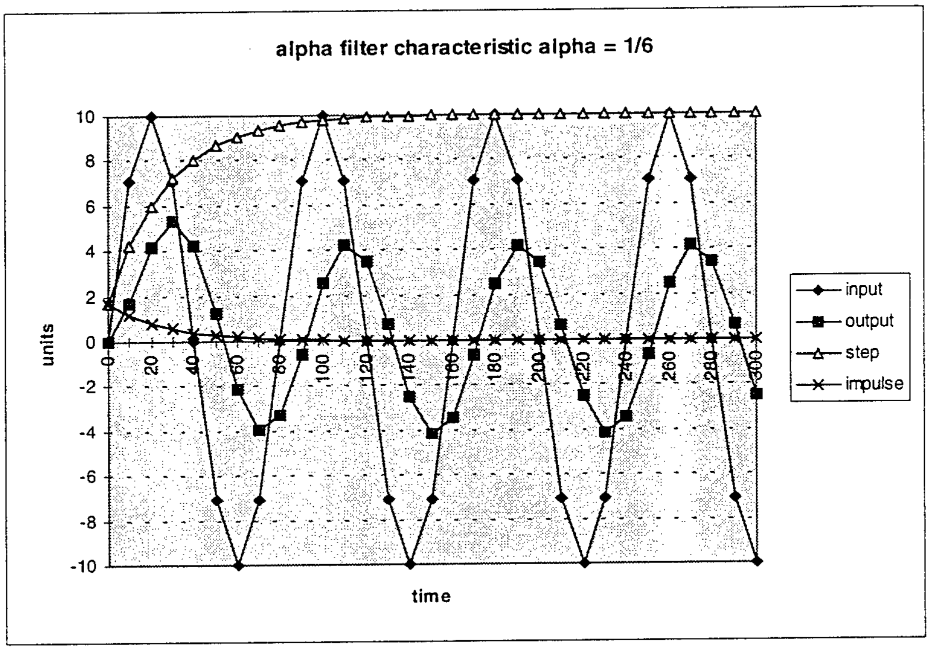

Figure 2: Sine, step and impulse response of alpha filter.

Figure 2 shows the filter response for various signals. The sine-period is 80 seconds, corresponding to 160m at 4 knots.

4.2.6 Hydraut

A dedicated interface to Hydraut (manufactured by Van Rietschoten & Houwens) was developed in order to acquire data about time, location, course and speed. Time and location are used only for stamping of other log data. Course and speed are used in real-time simulation.
OPPAS requests the data at 250ms intervals (longer in case of transmission errors) and the RTPI processing unit retrieves the data from OPPAS at 1 second intervals. A transmission error recovery algorithm guarantees that the reported time is

accurate to within 10s. Otherwise the time and location are reported as 'invalid'. The Hydraut course and speed are logged to file (with time and location stamp) every 10 minutes, provided there is a sufficient change from the previous value.

Table 4: Hydraut logging criteria.

Entity	Tolerance
Course	2 degrees
Speed	0.5 knots

4.2.7 Display/keyboard

The display/keyboard unit is connected to OPPAS. The data is fed through OPPAS to/from RTPI over the VME bus. This mechanism is described in document 23273.620/BN01. On OPPAS (the OS9 side), the connection to the display/keyboard unit is interrupt driven, using a standard serial device driver. The VME connection uses polling. A VME device driver would have incurred less overhead but would have required much more programming. For now, OPPAS can cope with the extra processing and therefore an interrupt driven device driver is not really necessary. The MSDOS side also uses polling but on this side there is no alternative because the PME board is not equipped with a VME-bus interrupter (the XVME board is).

4.3 Simulation model

The simulation model is a specialised version of HUNTOP with several extensions. In HUNTOP, as in real hunting operations, there are relatively few mines and the hunter sails a complicated track in order to hunt all mines. In order to obtain relevant statistical data, lots of simulation runs are necessary. Therefore a different approach was exercised in RTPI. Instead of few randomly scattered mines, there are numerous mines on a regular grid. A single straight track is sailed instead of a user-definable meander track. Doing so yields lots of statistical data within a single run. Of course, no operator can cope with so many mines, therefore the operator performance is computed using one of three pre-defined mine densities, independently of the simulated number of mines. The actual number of simulated mines depends upon the sonar search window, the bottom profile and the setting of the 'fast/accurate' button.

4.3.1 Module Autopilot

The autopilot travels a straight track such that the entire minefield passes once through the sonar window.

4.3.2 Module Bottom

The bottom contains the hills, see the User's manual for an explanation of the hill parameters.

4.3.3 Module Oparea

The operation area defines the minefield. As stated earlier in this chapter, the minefield generation depends largely on the bottom profile. When there are no hills or the direction of travel is along the hills, only a single line of mines across the hunter's track is simulated (the length of the field is zero). The width of the field depends on the sonar settings only.

Table 5: Minefield width as function of sonar range and sector angle.

Width	30	60	90
400	207.0	400.0	565.7
600	310.6	600.0	848.5
900	465.9	900.0	1272.8

The length of the field depends on the sonar range and relative hill orientation. When the direction of travel is perpendicular to the hills, the length equals the top to top distance of the hills. At any other angle (except along the hills), the vertical field size is longer than the top to top distance but never longer than the sonar range. The mine spacing depends on the hills and on the 'fast/accurate' button. Some spacings are expressed in 'L' which is one third of the length of the steepest hill slope (unless that slope is vertical).

Table 6: Mine spacing for 'accurate' simulation.

direction	along (φ=90°)	almost along	any angle (φ)	perpendicular (φ=0°)
horizontal spacing [m]	**Min(L, 5)**	**Min(L, 5)**	**Min(L/sinφ, 5)**	**5**
vertical spacing [m]	**single row**	**5 rows**	**Min(L/cosφ, 5)**	**Min(L, 5)**

Table 7: Mine spacing for 'fast' simulation.

direction	along (φ=90°)	almost along	any angle (φ)	perpendicular (φ=0°)
horizontal spacing [m]	**Min(L, 10)**	**Min(L, 10)**	**Min(L/sinφ, 10)**	**10**
vertical spacing [m]	**single row**	**5 rows**	**Min(L/cosφ, 10)**	**Min(L, 10)**

4.3.4 Module Simulator

The simulator performs the actual simulation runs and determines the P(y) curve. From the P(y) curve the simulator computes the A and B values. This module also incorporates the algorithm for the computation of the optimal depression angle. These algorithms are described in document 23273.660/BJ01.

4.3.5 Module Sonar

Although this module has no special provisions for RTPI, there is one sonar issue which must be understood. The sonar object has an attribute called 'look_angle' which is the horizontal angle of the sonar beam relative to the ship. In the general HUNTOP model, this attribute is allowed to have any value. In RTPI however this value is fixed, not measured and not user definable. For P(y) and A/B to be meaningful, this value must be set to zero. In actual RTPI operation, the true look angle (as set by the sonar operator) should also be zero (looking in the forward direction) because the reverberation values might be dependent on this angle.

4.3.6 Module Sonar Operator

The sonar operator module (sonope) contains the operator curves as defined by GESMA ("Performance des operateur en detection de mines" by Roger Philippart). Different curves are provided for low, medium and high mine densities.

Table 8: Object densities.

Listbox entry	Object density [km^{-2}]
Low	< 26
Medium	26 - 60
High	> 60

4.3.7 Module Water Volume

The watervolume module is the most complex module in the model. It performs the ray-tracing and determines the visibility of objects. Objects might be hidden by hills. Furthermore this module computes the reverberation and absorption for a given object. Bottom-, volume- and surface reverberation are computed independently. RTPI is configured to use the 'SeaRays' model for reverberation but a proprietary 'HUNTOP' model is available for bottom reverberation.
When RTPI is started with the appropriate arguments, it is possible to generate a file which lists both the calculated and measured reverberation levels as a function of the 'ray_time' (the time for the sound to travel to the current object and back). This feature is very useful in tuning the system during the operational evaluation.
Two absorption models are available: 'Schulkin' and 'Garrison'. RTPI is configured to use 'Garrison' which accounts for the Boric Acid contribution (for which the pH is needed).

4.3.8 Other modules

Many more modules are contained in RTPI which were not mentioned in this chapter. Some define very generic classes like 'Boolean', 'Coordinate' and 'Curve'. Others classes are specific to HUNTOP but not to RTPI and are omitted for brevity. Full documentation can be found in the software documentation (23273.650/BB01).

5. Documentation

The quality assurance programme applicable to this project (AQAP 1) requires consistent documentation and document identification. In this chapter all documents subject to configuration management are listed.

5.1 Introduction

All documents generated as part of the RTPI project are identified by a unique identification. The format of this identification is:
23273.www/XXnn
In this identification '23273' is the internal TNO-FEL project number, 'www' is a 3 digit number which identifies the work package and XX defines the document type. The two trailing digits 'nn' are used for various purposes like sequence number, revision number or volume number. The work package numbers are defined in the project plan (23273.000/AA01).

Table 9: Document types.

Identification	Document type
AA	project plan
AB	work packages, financial plan
AC	integration, installation and test plan
AF	quality assurance plan
AV	minutes of external meetings
AZ	memoranda
BB	system specification
BC	interface specification
BH	system design
BJ	software design
BN	detailed software design
BV	minutes of internal meetings
CB	hardware integration
CH	test plan
CK	test description
CO	test report
DA	user's manual
DB	system description
FA	configuration registration
FM	external reviews

5.2 Document overview

An overview of all documents delivered in the course of the project is presented in Appendix A. The table shows the documents identification number, a brief description and the latest version number when a version number was assigned.

6. Future Research

6.1 Validation and verification

Certain aspects of the RTPI prototype need validation before the system can be used in an operational environment. An operational evaluation is needed to proof the concept of performance prediction by means of simulation. Furthermore the acquisition and processing of measurement data need to be verified. This verification includes the accuracy and reliability (repeatability) of the measurements, most notably the sound velocity and reverberation measurements. Also the filtering of data must be evaluated. Currently filtering is applied to reverberation, depression angle and pH. The current filter characteristics are based on estimates of physical error sources, sampling times and desired response times. Real-world measurements are necessary to determine whether these filters should be tuned or enhanced (e.g. higher order filters).
The frequency of data logging needs to be evaluated. Current logging intervals are based on estimated rate of change and available disk space (reasonable amount of floppy disks and crew effort).
The ease of use of the system needs to be evaluated in order to derive system requirements for the series production. Especially the number of screens, the depth of the menu-structure and the amount of information on the screens must be evaluated.
Though the HUNTOP simulation core has been validated in previous trials, certain aspects specific to the RTPI implementation may need further attention:

- The use of measured reverberation; consistency and differences with the model must be checked and explained.
- Optimal depression angle computation; RTPI maximises the W value, evaluation should show whether ‘aggregate contrast’ is a better criterion.
- Fixed pitch (grid) minefield; in rare cases the number of mines may be too limited or the fixed pitch of the mines may cause aliasing problems. It should be investigated whether this occurs in practice.

6.2 Integration within a Command and Control System

The current version of RTPI is a prototype, it is intended to demonstrate feasibility and to gain experience with such a system. RTPI has interfaces which may not be present in the future. Future mine hunters may lack a PAP and hence OPPAS, though a similar system may be present. Therefore in the future, it is advantageous to interface RTPI to a Command and Control (C2) system. In this way, RTPI is connected to one system only. This still leaves the options of implementing RTPI as a normal application on the C2 platform(s) or to implement RTPI on a dedicated platform.

Table 10: Advantages of platform options.

Application on C2 platform	Dedicated RTPI platform
reduced hardware costs	no performance penalty on C2 system
flexible system design	high level of system integrity
uniformity in operating systems	freedom of operating system
less space occupation	lower implementation and maintenance costs
uniformity with C2 environment	uniformity with RTPI prototype environment

The actual implementation also depends on the boundary between RTPI and C2 system. When the C2 system is made responsible for all data acquisition (and winch control) and logging, RTPI shrinks to the simulation model and the user-interface which has to be modified anyway. In this case, implementation as just another application on the C2 system makes more sense than a separate platform. On the other hand, when RTPI is responsible for the acquisition of real-time data and winch control (data which is not necessary for other C2 applications), a dedicated RTPI computer which interfaces directly to the measurement unit is quite attractive. Other data can be obtained from the C2 system by any communications protocol.
Integration with a C2 system gives access to new sources of RTPI input data. Especially minefield data, which must be entered manually at the moment, can be obtained from an electronic map.

6.3 Effects of different sonar equipment

In the future, different sonars than the DUBM21 may be used. In general, this will mean that the interface to the sonar will change and that the sonar model needs to be rebuilt. The interface encompasses the settings of various buttons and controls. Possibly (likely) new controls need to be added to the interface and the translation from control to real-world value has to be changed. Also the way in which the reverberation signal can be derived, may change.
The changes to the sonar model may be extensive, especially when a PVDS (Propelled Variable Depth Sonar) will be used instead of a hull mounted sonar.

6.4 Off-line use and tools

6.4.1 Log files

During normal operation RTPI acquires and logs an abundance of data. This data is intended for off-line analysis, storage for later use or construction of a database (e.g. by the Mine Warfare Data Centre (MWDC). Currently there are no tools available for the handling of the logged data. The amount of data is typically 1.44M per day.

Though the file format is plain ASCII and can be imported into for instance 'Excel™', it is recommended to use a dedicated tool for the translation because the file format is not guaranteed to remain the same in future versions.

6.4.2 Resource files

RTPI uses resource files in its computations as a user selectable source of pre-defined data. The user can add and remove resource files to/from the RTPI system through the database maintenance screen. Currently there is no tool available to create these resource files. The resource files are plain ASCII files and can be edited using any text editor. This technique is strongly discouraged however because errors in this procedure can corrupt the file which can easily crash the system. Therefore it is recommended to use a dedicated resource editor which not only ensures system integrity but also ensures file compatibility across different versions. Moreover, such a tool could allow translation from measured profiles into resource profiles.

6.4.3 Performance calculation

The main purpose of RTPI is to compute the performance of a mine hunting operation (detection phase). These computations can be done using real-time data or using stored data. The latter possibility is useful for planning and what-if analysis. It can be desirable to perform these computations also off-board, e.g. for validation or further analysis. At this time however, RTPI/HUNTOP are not deliverable as desktop PC programs. Depending on the desired level of emulation, it is technically possible however to port RTPI to a desktop PC.

7. Signature

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Group leader

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Author

Appendix A Documentation

number	title	version
000/AA01	Project plan (internal)	1.0
000/AA02	Project plan	1.0
000/AB01	Work breakdown	x0.1
000/AB02	Planning division 1	x0.1
000/AV01	Minutes meeting 08-09-94 (weekly)	
000/AV02	Minutes meeting 15-09-94 (with MEOB)	
000/AV03	Minutes meeting 22-09-94 (weekly)	
000/AV04	Minutes meeting 26-09-94 (with MEOB)	
000/AV05	Minutes meeting 29-09-94 (weekly)	
000/AV06	Minutes meeting 04-10-94 (with MEOB)	
000/AV07	Minutes meeting 10-10-94 (1st proceedings meeting.)	
000/AV08	Minutes meeting 13-10-94 (weekly)	
000/AV09	Agenda 2nd proceedings meeting. (template)	
000/AV10	Minutes meeting 12-12-94 (2nd proceedings meeting.)	
000/AV11	cancelled	
000/AV12	Minutes meeting 06-01-95 (3rd proceedings meeting.)	
000/AV13	Minutes meeting 24-04-95 (4th proceedings meeting.)	
000/AV14	Minutes meeting 12-06-95 (5th proceedings meeting.)	
000/AV15	Minutes meeting 31-08-95 (6th proceedings meeting.)	
000/AV20	Minutes meeting 30-10-95 (7th proceedings meeting.)	
000/AV21	Minutes meeting 09-01-96 (8th proceedings meeting.)	
000/AV22	Minutes meeting 11-03-96 (9th proceedings meeting.)	
000/BZ01	End of phase 1 (letter)	
100/AF01	Quality assurance document	1.1
100/FA01	this document	3
400/AC01	test plan	x0.1
400/BB01	Functional System Specification	1.0
400/BB02	User Interface Document	1.1
400/BB03	HUNTOP specification	1.0
401/BC01	RTPI-OPPAS IDD	1.0
402/BC01	RTPI-MEOB IDD	2.1
403/BC01	RTPI-HYDRAUT IDD	2.1
400/FM01	Comments of Mr. Frohn (RNLN) on phase1 deliv.	
400/FM02	Reaction to 400/FM01	
500/CH01	Emulator test plan	0.2
500/CO01	Emulator test report	1.1
501/CH01	Hydraut emulator test plan	0.2
501/CO01	Hydraut emulator test report	1.1
610/BM01	OPPAS hardware modifications documentation	0.1
620/BN01	OPPAS interface design document	1.1
631/BH01	OOD-OOP document of the measuring unit	0.2
641/BH01	OOD User Interface	0.4
642/BH01	OOD-OOP document for the database	0.2
650/BB01	HUNTOP RTPI Object model	x1.2
660/BJ01	Optimal depression angle calculation	
700/CH01	Factory acceptance test plan	1.0
700/CK01	Factory acceptance test description	x0.1

number	title	version
700/CO01	Report to RNLN concerning FAT (letter)	
700/CO02	Factory acceptance test report	x0.1
700/CO03	Reverberation measurements of FEL-MEOB trial	x0.1
700/CO04	REACT reverberations used during FAT	x0.1
700/CO01	EMC test results	
700/DA01	User's Manual	x0.1
200/DB01	Final report	
800/DA02	Release notes	
800/DA03	Release notes Release 1.1	
800/DA05	Release notes Release 1.3	
700/CZ01	Packing list hardware	
700/CZ02	Packing list documentation	
800/FM01	Comments regarding installation	

REPORT DOCUMENTATION PAGE
(MOD-NL)

1. DEFENCE REPORT NO (MOD-NL)	2. RECIPIENT'S ACCESSION NO	3. PERFORMING ORGANIZATION REPORT NO
TD97-0147		FEL-97-A219
4. PROJECT/TASK/WORK UNIT NO	**5. CONTRACT NO**	**6. REPORT DATE**
6023273	A93KM754	September 1997
7. NUMBER OF PAGES	**8. NUMBER OF REFERENCES**	**9. TYPE OF REPORT AND DATES COVERED**
26 (incl 1 appendix, excl RDP & distribution list)	-	

10. TITLE AND SUBTITLE

RTPI Prototype
Final Report

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14. SUPPLEMENTARY NOTES

The classification designation Ongerubriceerd is equivalent to Unclassified, Stg. Confidentieel is equivalent to Confidential and Stg. Geheim is equivalent to Secret.

15. ABSTRACT (MAXIMUM 200 WORDS (1044 BYTE))

The 'Real-Time Performance Indicator (RTPI) prototype' system assesses the quality of mine detection using a sonar. The system is designed for the 'Alkmaar' class mine hunters equipped with dedicated instrumentation for measurement of the sound velocity profile, the absorption and reverberation in the vicinity of the hunter at the time of the operation (hence real-time). The quality of mine detection is expressed as a detection probability curve which indicated the detection probability as a function of the athwart distance and as A and B values which indicate the characteristic detection width and the characteristic detection probability. The system is enclosed in the OPPAS rack and uses many of the OPPAS system interfaces. RTPI incorporates the HUNTOP simulator which simulates a mine-hunting operation (detection phase) using real-world environment data and computes the desired probabilities.
This report describes the development of the TNO-FEL part of the system.

16. DESCRIPTORS	IDENTIFIERS
Sonar Naval mine detection Mine hunting Computerized simulation	Sonar performance indicator

17a.SECURITY CLASSIFICATION (OF REPORT)	17b.SECURITY CLASSIFICATION (OF PAGE)	17c.SECURITY CLASSIFICATION (OF ABSTRACT)
Ongerubriceerd	Ongerubriceerd	Ongerubriceerd
18. DISTRIBUTION AVAILABILITY STATEMENT		**17d.SECURITY CLASSIFICATION (OF TITLES)**
Unlimited Distribution		Ongerubriceerd

Distributielijst

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4.	HWO-KLu*)
5.	HWO-KM
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20.	Archief TNO-FEL, in bruikleen aan Ir. J.F.J. Vermeulen
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26.	Archief TNO-FEL, in bruikleen aan Ir. A.M. van der Weiden
27.	Documentatie TNO-FEL
28 t/m 30.	Reserve
	TNO-PML, Bibliotheek**)
	TNO-TM, Bibliotheek**)
	TNO-FEL, Bibliotheek**)

Indien binnen de krijgsmacht extra exemplaren van dit rapport worden gewenst door personen of instanties die niet op de verzendlijst voorkomen, dan dienen deze aangevraagd te worden bij het betreffende Hoofd Wetenschappelijk Onderzoek of, indien het een K-opdracht betreft, bij de Directeur Wetenschappelijk Onderzoek en Ontwikkeling.

*) Beperkt rapport (titelblad, managementuittreksel, RDP en distributielijst).
**) RDP.